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Status of *Bemisia tabaci* in the Mediterranean Countries: Opportunities for Biological Control[1]

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Outbreaks of *Bemisia tabaci* along the Mediterranean began about 20 years ago. They occur on cotton and vegetables and often cause severe damage. Such outbreaks are typified by initial high populations that later decrease, while natural enemies apparently become important controlling factors. Both predators and parasitoids attack the pest, but the significance of any one factor in controlling *B. tabaci* is unclear. It is important to integrate the pest management systems of various crops with the preservation of their natural enemies. Information is sparse regarding the relative toxicity of pesticides to the natural enemies and in regard to the exact methodology to be used for *B. tabaci* management, especially in vegetable crops. Additional natural enemies of *B. tabaci* should be introduced, and both new and existing ones should be preserved in the nonagricultural environment as well as in the particular crop systems. Experiments should be conducted to establish the role of different natural enemies and their susceptibility and relationships to existing pest control practices.

KEY WORDS: **pest management; *Bemisia tabaci;* cotton; vegetables; greenhouse culture; natural enemies; biological control; insecticide resistance; biotypes; whiteflies; sweetpotato whitefly.**

INTRODUCTION

Bemisia tabaci Gennadius was described from Greece (Gennadius, 1889), although it probably originated in India or Pakistan (Mound, 1983). Its presence in the Mediterranean countries has been well established throughout this century (e.g., Avidov, 1956; Gomez Menor, 1943). Although known as a severe pest mainly in the eastern part of the Mediterranean, it became a pest in the western part only recently, probably with the introduction of infested material from the New World.

B. tabaci is a pest both in greenhouses and out of doors. In greenhouses it may occur year round and mainly affects vegetables and flowers, both as a virus transmitter and as a direct pest (sooty mold production and plant sucking). Outdoors it is a major pest of summer crops such as cotton, vegetables, and ornamentals. Being thermophilic, it has been a more severe pest in the warmer, eastern basin of the Mediterranean, including Israel, and Turkey.

The history of severe infestations of cotton along the Mediterranean dates back to 1974 when *B. tabaci* became the most important pest in the Cukurova region of Eastern Turkey (Sengonca, 1975). It showed up as a severe pest in Israel during 1976/1977 (Gerling *et al.*, 1980), whereas in Egypt its infestations have become severe in both cotton and tomatoes during the last 4 to 5 years (personal communication). Although it has not yet reached the proportions of a major outbreak, *B. tabaci* has recently become a pest of poinsettias in Italy, France, and Spain. It also infests tomatoes and other vegetables in Spain and Algeria (J. Arno, personal communication, Benmasoud-Boukhalfa, 1991). In Turkey and Israel, the initial appearances of the commercial infestations on cotton were accompanied by very large numbers of whiteflies and severe damage. Since then, the populations have fluctuated, with some years more severe than others. The situation in Israel was monitored during much of this period and will be given as an example to illustrate some important points.

The outbreaks of *B. tabaci* populations in Israel were the most severe during the first 11 years (1977–1988). Concurrently, there was a shift in the regional distribution of the more severely affected regions. Of the originally "trouble prone" regions that included the Jordan Valley, the Beit Shean Valley, the inner hill country, selected spots along the coast, and the northern Negev, only the latter two are now problematic. The Beit Shean Valley, where whitefly populations were

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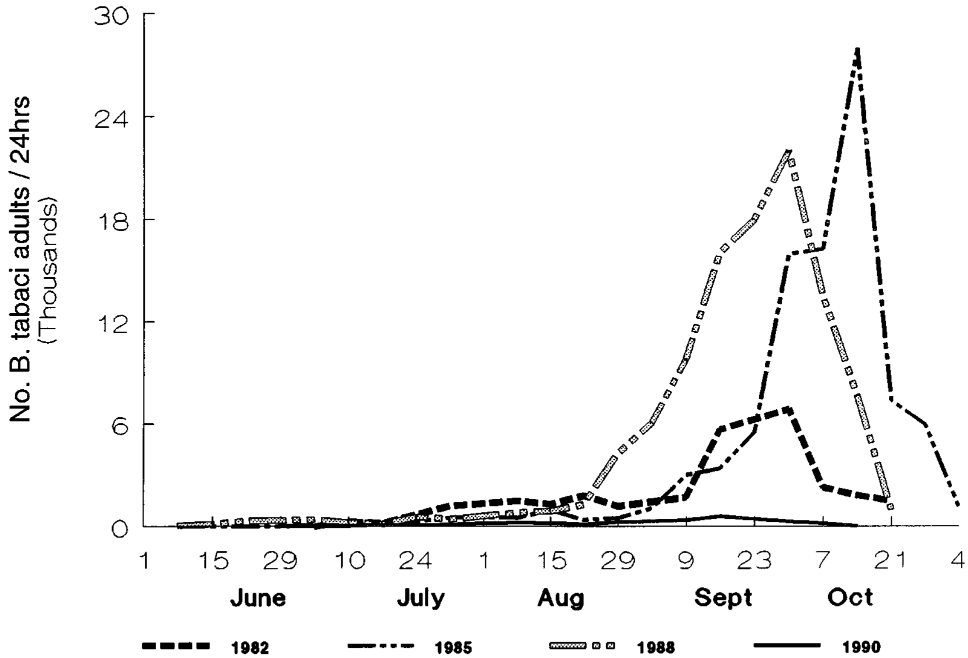

FIG. 1. Yellow trap catches of *B. tabaci* at the Eden experimental farm, Beit She'an Valley, showing the high population level until 1988, and the low level in 1990.

monitored continuously up to 1990, reflects the changes that *B. tabaci* has undergone as seen through yellow trap catches (Fig. 1).

The recent decline in the severity of *B. tabaci's* pest status is especially noticeable on host plants that are not in the agroecosystem and therefore are not treated with insecticides. For example, the heavy populations on garden poinsettias and lantana hedges (Gerling, 1984), that usually accompanied outbreaks of *B. tabaci* during the early years, have attenuated during the last 4–6 years.

Recent studies have shown that the name *B. tabaci* incorporates a number of genetic entities, ranging from biotypes that differ mainly in electrophoretic and nucleic acid patterns and host plant ranges to more significant differences, suggesting that the present name *B. tabaci* may actually harbor more than one species (Bedford *et al.*, 1992; Costa *et al.*, 1991; Liu *et al.*, 1992; Perring *et al.*, 1989, 1993). Indeed, recently, a new species *Bemisia argentifolii* Bellows and Perring has been described for some of the outbreak causing individuals that had previously been identified as *B. tabaci* (Bellows *et al.*, 1994).

THE PRESENT SITUATION

The populations of *B. tabaci* in the Mediterranean countries probably contain some elements of the original local biotypes [with the typical virus transmitting capacity and electrophoretic patterns (Cohen and Melamed-Madjar, 1978; Wool and Greenberg, 1990)]. In addition, several of the present populations were identified as the newer B biotype. According to Bedford *et al.* (1992), who examined three Mediterranean populations, the population from Cyprus was identical to biotype B that occurs in California, while that from Israel differed from the latter only in its somewhat more limited host plant range, whereas the Turkish material differed in not causing squash silvering as well as in different esterase patterns, a different host range, and different adult behavior. Material collected from Murcia and Catalonia in Spain and from Egypt was identified as the B biotype by T. Perring (Perring *et al.*, 1993). Difficulty in determining the strain affiliation of *B. tabaci* is compounded by use of the electrophoretic method for strain differentiation (Dittrich *et al.*, 1990; Liu *et al.*, 1992; Bedford *et al.*, 1992; Perring *et al.*, 1993) because the esterase bands detected through electrophoresis may vary with the degree of exposure and/or resistance to insecticides (Bloch and Wool, 1992).

The pest cycle on cotton usually starts in July with the migration of adults from vegetables (Gerling, 1984) and ends at defoliation time, about September. During this 3-month period, the pest becomes established and may reach very high numbers and develop ca. five generations. According to Horowitz (1986), a developmental pattern that consists of four phases—moderate, exponential, stabilized, and decline—is typical of cotton infestation under such conditions.

Other outdoor crops that suffer from attacks of *B. tabaci* include summer grown vegetables of the Cucurbitaceae, Solanaceae, and Crucifereae. Severe damage was limiting production of vegetables as early as 1931 in the Jordan Valley region of Israel (Avidov, 1956). Melons and cantaloupes continue to be heavily infested, although the use of modern insecticides such as IGRs and screenhouses for vegetable culture limit direct damage and allow for normal crop production. Tomatoes, when grown out of doors, are attacked by *B. tabaci* but direct damage is only minor. The main concern is due to the transmission of Tomato Yellow Leaf Curl Virus which, if it hits the plant early, precludes fruit production. Eggplants often develop very high populations, which reduce yield and may produce enough honeydew and sooty mold to cover the plant and fruit and cause substantial damage. Tobacco, which was the host plant from which the pest was originally described as maintaining very heavy populations (Gennadius, 1889), is only rarely a host plant of *B. tabaci* under most Mediterranean conditions. Beans and cole crops have not been considered subject to *B. tabaci* damage until recently. In Israel, heavy populations on these plants are known only from the last 3–4 years and coincide with the apparent appearance of the B strain or biotype of the pest in Israel.

The situation within greenhouses differs markedly from that in the open. This is due to both the climatic conditions and the types of crops grown. Tomatoes and cucumbers are grown extensively under greenhouse conditions and both are susceptible to *B. tabaci*-borne viruses. This is especially severe in the fall, when large whitefly populations leave summer crops such as cotton and melons and invade the greenhouses in which the fall and winter crops have recently been planted. Infestation at that early stage may injure the crops and cause severe losses. Other susceptible crops grown under greenhouse conditions include poinsettias, roses, and gerberas.

OPPORTUNITIES FOR BIOLOGICAL CONTROL

General Considerations

The invasion of new *B. tabaci* biotypes has usually resulted in very high infestation levels, as observed in Israel from 1976 on, for a number of years. With time, the outbreak levels declined until the pest reached the present status, in which it still remains serious but has lost much of its initial urgency. The cause for this change has not been determined experimentally and its exact reasons are not known. Three factors will be considered here: (1) A change in the efficiency of some natural enemies; (2) a change in the pest's fitness; and (3) a change in pest management tactics.

1. *B. tabaci* is attacked by parasitoids, predators, and fungal diseases. Of the latter, no important, population reducing, species have been found in Israel (Fransen, personal communication) or recorded in other Mediterranean countries. The parasitoid fauna includes two genera: *Eretmocerus,* of which only *mundus* Mercet has been taxonomically identified, and several species of *Encarsia.* Predators of *B. tabaci* are usually not species specific and may belong to a number of taxonomic groups (Gerling, 1990).

The ultimate measure of natural enemy efficiency is the degree to which it was successful in containing the pest population. However, since both parasitoids and predators of *B. tabaci* occurred naturally in the field and their complete removal as a means for measuring their effects was not possible, relative measures such as percentage parasitism and predator host ranges have been used for assessing changes in efficiency.

Attempts to introduce new species of parasitoids of *B. tabaci* have met with only partial success. Thus, the principal species that are collected in each sample throughout the years are *Encarsia lutea* (Masi) and *Eretmocerus mundus.* Occasionally, other species of *Encarsia* like *inaron, formosa,* or *partenopea* are found attacking *B. tabaci* in Israel, and recently Kirk *et al.* (1993) recorded *E. formosa* Gahan in Crete. Parasitism has typically been low during outbreak phases of *B. tabaci,* often reaching only a few percent, and high in low host populations, reaching over 60% (Gerling *et al.*, 1980). This picture has not changed since monitoring of parasitism began in 1977, but the prevalence of high parasitism occurring in low *B. tabaci* populations has greatly increased with the general decline of this pest (Fig. 2). No evidence exists that direct parasitoid activity was the *cause* of this general decline.

The predators *Chrysoperla carnea* (Stevens), *Orius* spp., several coccinellid species, and *Deraeocoris pallidus* Rueter, were the most prevalent in the sampled fields. However, as already noted by Dinkins *et al.* (1970), predators rarely peak on the same date from year to year. Moreover, their faunal and season composition also changed among places (Figs. 3 and 4).

The dietary habits and behavior toward *B. tabaci* at the onset of the outbreaks of 1976/1977 were observed for *C. carnea* (Bar and Gerling, personal observations). At present, this predator is able to complete its cycle on *B. tabaci* and will prey upon it in the field (Or, 1986). This is in contrast to our observations on *C. carnea* feeding behavior during 1978, when its larvae seemed to have difficulties handling *B. tabaci* nymphs as prey. Thus, *C. carnea* and possibly other predators, might have acquired the capacity to use *B. tabaci* as prey following continuous exposure to high populations for a number of years.

2. Following outbreaks, populations often return to their former, or to a similarly low, level, even without the use of pesticides. Such a natural decline in population levels may be brought about because the extensive population increase during the outbreak phase produced individuals that are comparatively less well equipped to cope with environmental hardships than

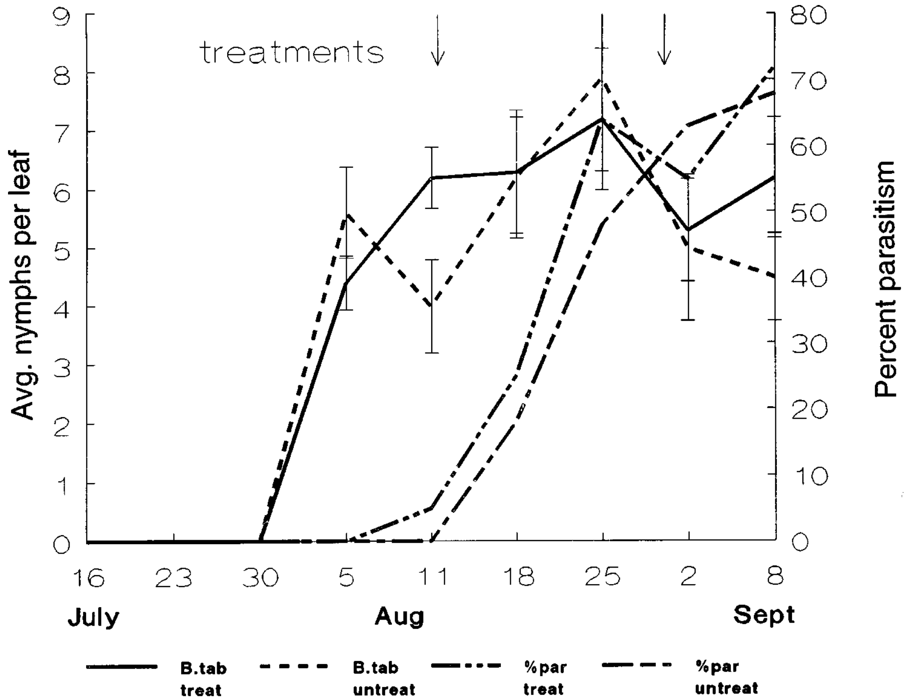

FIG. 2. Population fluctuations of *B. tabaci* and percentage parasitism at Zora, Coastal foothills, showing the levels of infestation and parasitism, with and without insecticide treatments.

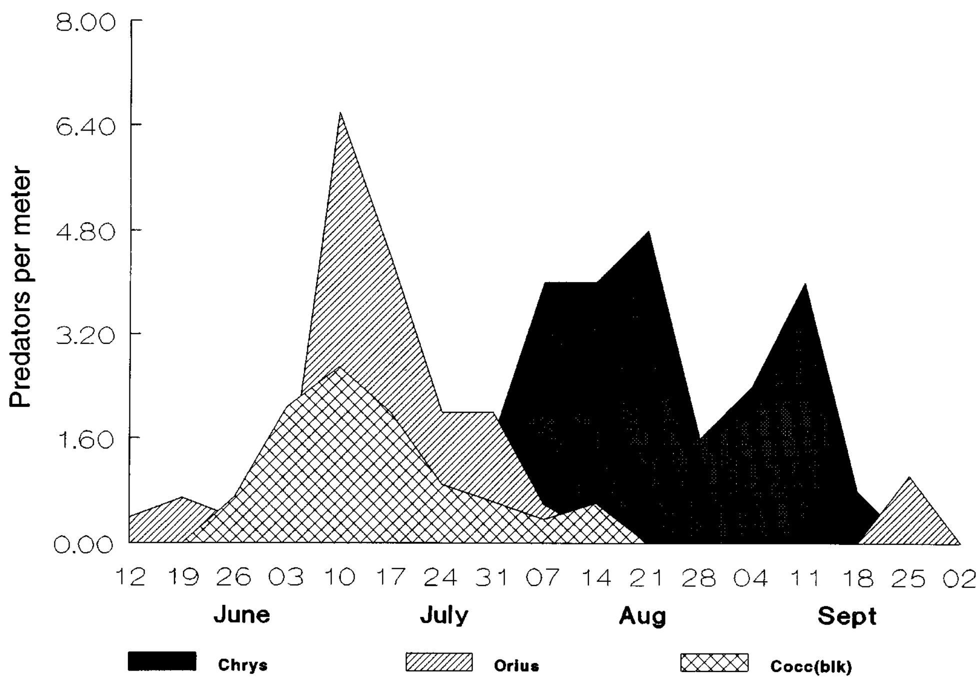

FIG. 3. Population levels of the predators *Chrysoperla carnea* (Chrys), *Orius* spp., and coccinellids, primarily of the genus *Scymnus* (Cocc(blk)) in untreated cotton field at the Eden experimental farm during 1990, showing that both coccinellids and *Orius* are almost entirely limited to the beginning of the season.

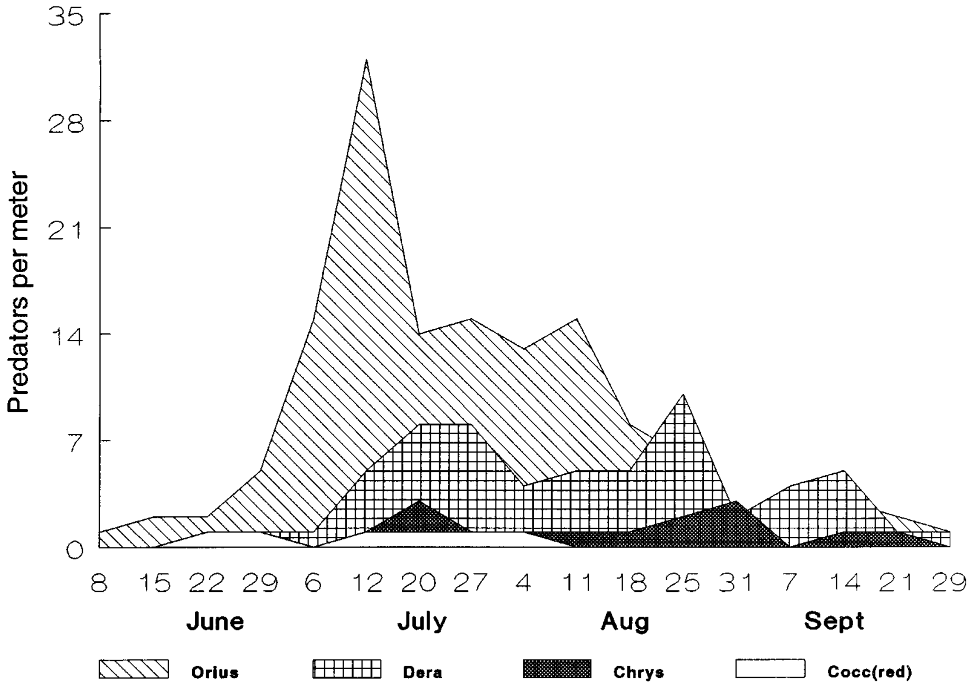

FIG. 4. Population levels of the predators *Orius* spp. *Deraeocoric pallens* (Dera), *Chrysoperla carnea* (Chrys), and coccinellids of the genera *Hippodamia*, *Coccinella*, and *Exochumus* (Cocc(red)) in an untreated cotton field at Kibbutz Zora during 1993, showing the seasonal occurrence and the relative abundance of the species.

those of the normal populations. Such lack of fitness has been discussed in relation to insecticide-resistant insects (Roush and Daly, 1990). This has been associated, in part, with the extensive input that the resistant insects have to invest in enzymatic systems like esterases. Such input reduces the amount of proteins that can be used for other, fitness-supporting, systems such as reproduction. In addition, behavior handicaps have been observed in the resistant strains.

Similar systems may also act upon *B. tabaci* at the population outbreak stage. The activity may materialize in two ways. First, the above-mentioned arguments may also hold for *B. tabaci* since its populations have been treated with insecticides over a long period of time and are highly resistant to insecticides (Dittrich *et al.*, 1990). Second, when attacking a plant, the whiteflies must overcome its defensive mechanisms, which include allelochemicals, cuticular formations, and cellular characteristics. We may assume that these defensive mechanisms are responsible for the differential in the reproductive rates and instantaneous rates of increase of *B. tabaci* shown by Powell and Bellows (1992) and also preclude the development of the whiteflies on many (nonhost) plant species.

At outbreak time, *B. tabaci* individuals develop on suitable hosts which facilitate the formation of extensive populations. However, as a result of the outbreak, very large numbers of adults take to the air. Many of these land on new host plant species that contain defensive mechanisms to which *B. tabaci* has not adapted. Consequently, a large percentage of the outbreak population may have to obtain sustenance on host plants that are, at best, suboptimal, resulting in reduced survival and oviposition rates. Such a condition may result in the observed increase in the host plant range, but may also serve as a mechanism for the reduction of *B. tabaci* populations.

3. Pest management tactics often override and interact with all other mechanisms of population outbreaks. For example, predator and parasitoid counts were conducted in cotton fields with untreated and treated plots. The parasitoids were often affected by insecticide applications to a lesser degree than the predators (Figs. 2 and 5–9). Thus, changes in predator efficiency are related to the pest management regimes in addition to their feeding habits. In the case of *B. tabaci* in Israel, a change in the practice of cotton pest management due to the encouragement of a drastic reduction in the use of insecticides, by the Cotton Production and Marketing Board, may have played a role in the change of *B. tabaci* populations. This policy, which brought about a reduction in treatments from maxima of 16 per season in 1986 (including 14 against *B. tabaci*) to about 6.6 per season during 1992 (including 2 against *B. tabaci*) together with the advent of long lasting, low toxicity materials such as IGRs, allowed the predator popula-

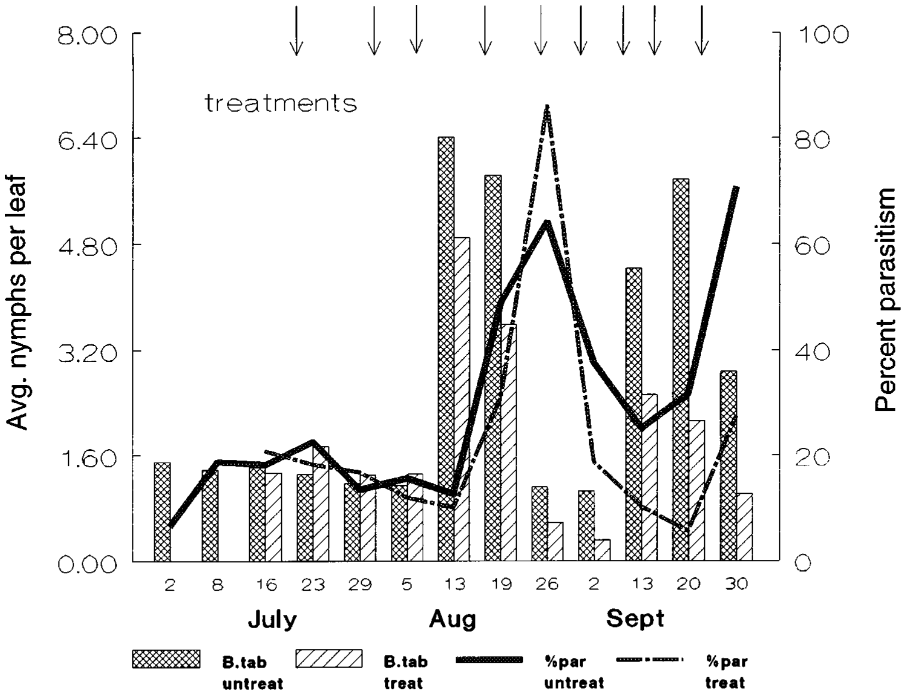

FIG. 5. Population fluctuations of *B. tabaci* and percentage parasitism at Ma'ale Gilboa, Beit She'an Valley, showing the levels of infestation and parasitism, with and without insecticide treatments.

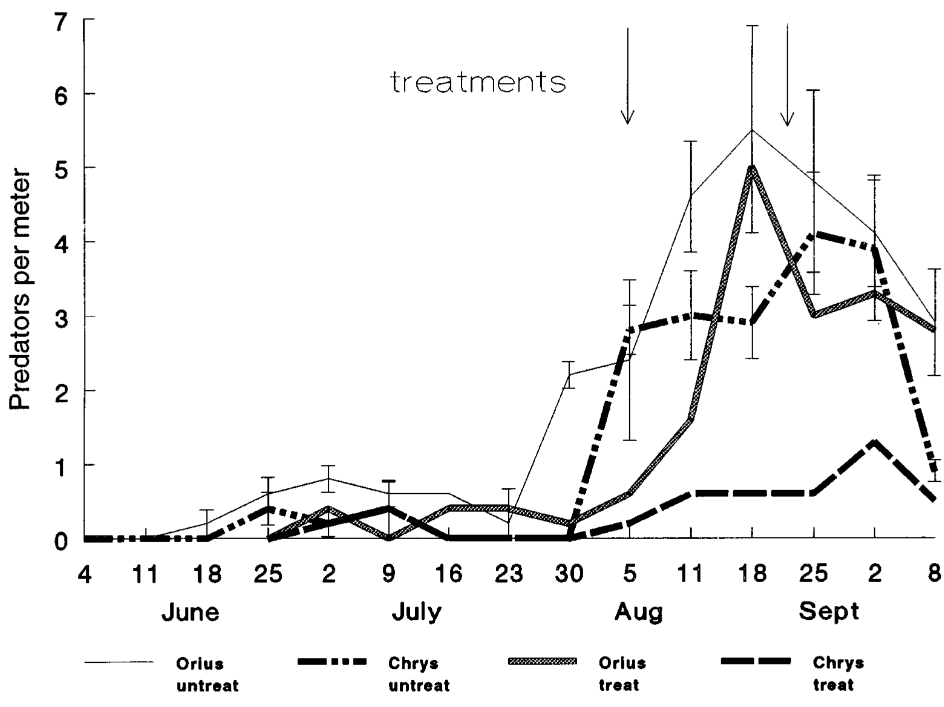

FIG. 6. Population fluctuations of *Chrysoperla carnea* and *Orius* spp. at Kibbutz Zora, Coastal foothills, showing the levels of the population, with and without insecticide treatments.

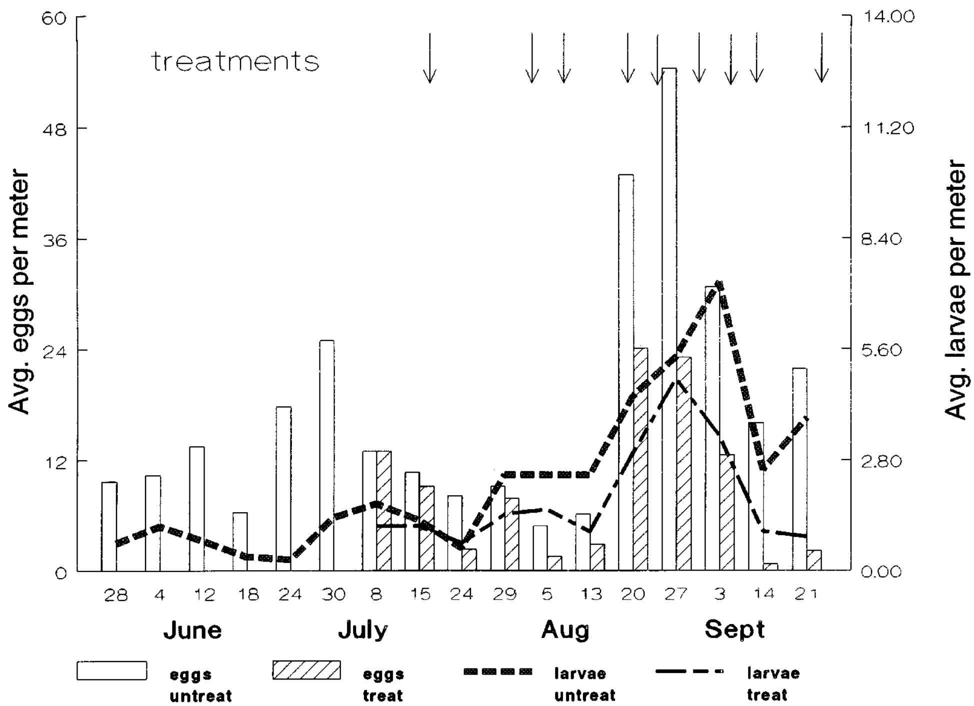

FIG. 7. Population fluctuations of *Chrysoperla carnea* at Maale Gilboa, Beit She'an Valley, showing the levels of the population, with and without insecticide treatments.

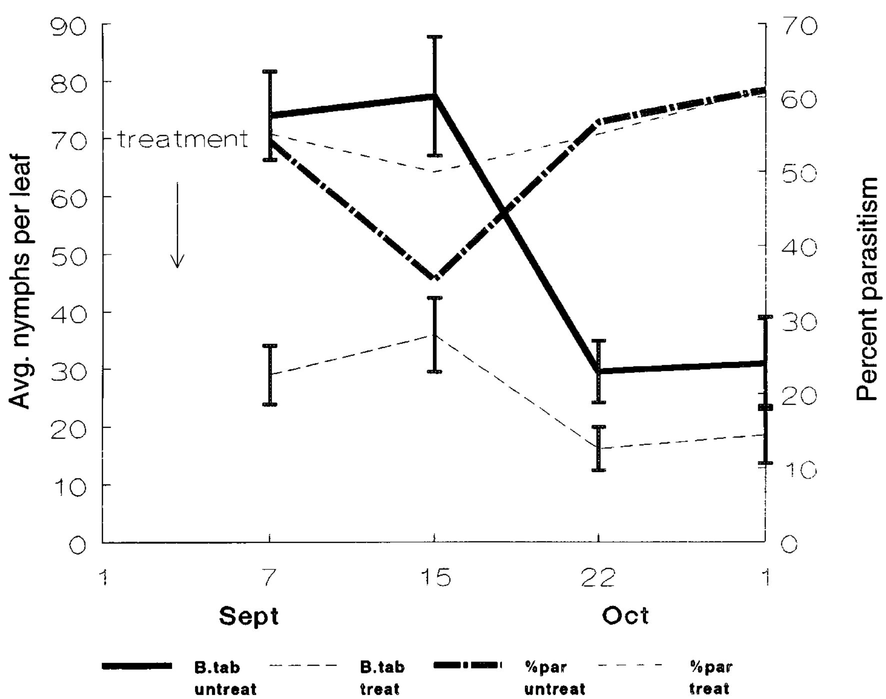

FIG. 8. Population fluctuations of *B. tabaci* and percentage parasitism at Mishmeret, coastal plain, showing the levels of infestation and parasitism, with and without insecticide treatments.

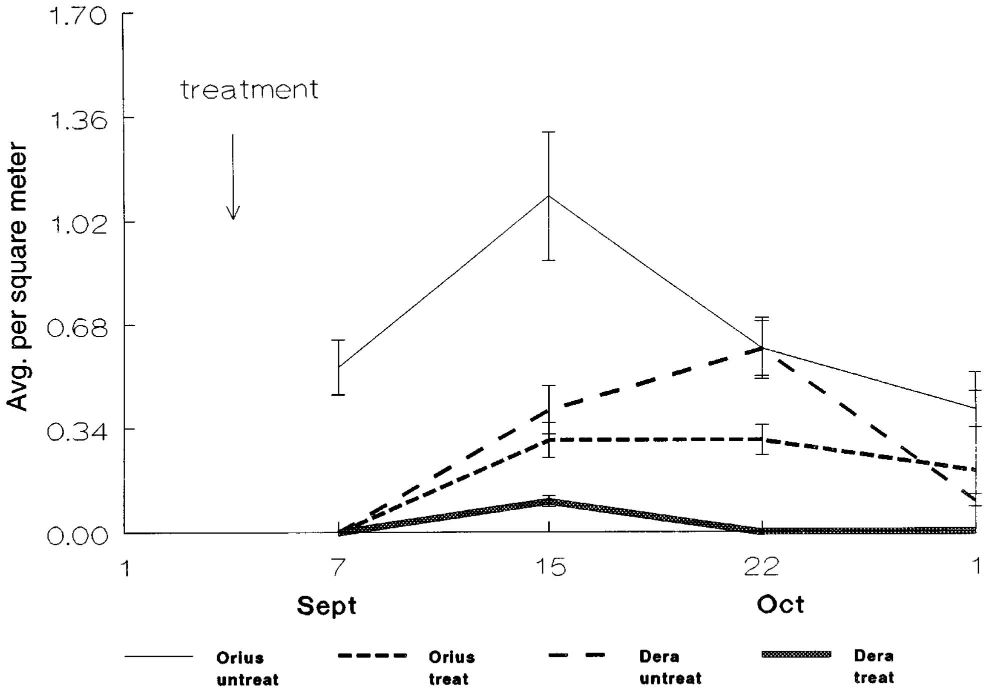

FIG. 9. Population fluctuations of two predator species occurring in Mishmeret, coastal plain, showing the levels of the populations, with and without insecticide treatments.

tion to increase, and most probably also contributed to the maintenance of lower overall *B. tabaci* populations. It also enabled the growers to manage whitefly resistance, resulting in fewer and more effective insecticide treatments.

Management strategies for *B. tabaci* must consider, among other things, whether the pest is in its initial, outbreak phase, when the impact of natural enemies is minor, or is at a later, more moderate phase of infestation, with established natural enemies responsible for its mitigation.

When embarking upon a pest management or biological control project, it is essential to define its goals, i.e., the desirable outcome of the particular activity that is undertaken. This is particularly true with a pest like *B. tabaci*. A tomato grower along the Mediterranean will define adequate control as the presence of zero adult whiteflies staying for longer than 30 min on his plants—which in turn will materialize as virus-free tomatoes. A cotton grower will quantify the pest as the numbers of nymphs capable of producing honeydew, while a grower of ornamentals will define his own specific thresholds. These control needs can only be satisfied if different strategies are employed, each aiming at a particular expression of the pest's potential for damage, while taking into consideration the other pest management problems relevant to the particular crop. However, in addition to the particular needs of each crop, one must also consider general, overall measures that will alleviate the pest situation, and thus facilitate biological control in each particular crop.

Management of *B. tabaci* through biological means, therefore, should include at least two steps: (1) Enhancing the impact of natural enemies of the pest in the environment in general, through both inoculation, using exotic natural enemies, and the conservation and augmentation of existing ones; and (2) introduction, augmentation, and manipulation of natural enemies that are particularly suitable for management of the pest under *specified conditions* like greenhouses, cotton fields, or vegetables.

Specific Examples

Enhancing the impact of natural enemies in the environment. An examination of the natural enemy lists and records of *B. tabaci* (e.g., Gerling, 1986; Cock, 1986; Osborne *et al.*, 1990) reveals that numerous potential predators and parasitoids of this pest exist in many countries. Moreover, many of the parasitoid species are not species specific and are able to enlarge their host range following exposure to additional whitefly species (Gerling, 1990; Viggiani and Gerling, 1994). Consequently, the introduction and outbreak of *B. tabaci* in a new habitat will often be followed by an adoption of this species in the diet or host range of local natural enemies. However, such an increase in the dietary range of the natural enemies may take several generations during which behavioral and other selection pressures will affect the success of the newly acquired interaction.

Therefore, the program to increase the overall impact of natural enemies on the pest must include both the introduction of known natural enemies of *B. tabaci* that are absent in the particular area of infestation and the augmentation of the local natural enemy fauna. The establishment of additional natural enemies through both methods will increase the enemy complex attacking *B. tabaci* and thus may bring about higher natural mortality of the pest (Price, 1991). We should also consider the fact that the impact of a local natural enemy fauna will probably increase with time. Efforts should be made to encourage this process and to accelerate it through various conservation methods which include the judicious and selective use of insecticides, cultural techniques, and various other manipulations (DeBach and Rosen, 1991; Gerling, 1992).

BIOLOGICAL CONTROL OF *B. tabaci* IN COTTON

Cotton is usually plagued by numerous pests in addition to *B. tabaci*. These include aphids and several species of lepidopterous larvae. In the Mediterranean countries, infestation by *Helicoverpa armigera* (Huebner) and the pink bollworm, *Pectinophora gossypiella* Saunders, may occur and must be controlled early in the growing season, when predators of the genera *Orius* and coccinellids are most abundant (Figs. 3 and 4) and while whitefly populations are still incipient (Figs. 2 and 5). Since the control measures include insecticide treatments, they may also kill the predators at a time when these should be preserved in order to prevent later pest outbreaks.

The danger of disrupting the activity of natural enemies of the whiteflies can be overcome in this case by a number of measures, including careful scouting and withholding of treatment against *H. armigera* which usually does not cause economic damage (Bar *et al.*, 1979), the use of nonpoisonous preparations such as *Bacillus thuringiensis* Berliner against *H. armigera* or of pheromone preparations for early disruption of pink bollworm mating systems, and the use of insecticides having a limited killing range which are aimed at solving specific problems. If the whiteflies are prevented from earlier buildup and if adequate natural enemies exist, there are good chances that the *B. tabaci* population levels will also remain low at this time (Fig. 1, 1990). However, should the natural enemies' activity not contain the whitefly population, the use of selective materials may be necessary. Materials that affect mainly whitefly adults and early nymphal instars like IGRs and detergents are preferable since they have only a minor effect upon whitefly pupae or parasitoids (Gerling and Sinai, 1993). Consequently, if these materials are used late in the season, when the whitefly populations tend to be high but most predator populations are relatively low (Figs. 3 and 4), a decimation of the whiteflies will follow with minimal damage to the natural enemy populations. Moreover, since the parasitoids mainly attack the later whitefly instars and develop therein (Gerling, 1990), they will be able to continue and find suitable hosts among those whitefly immatures that have escaped the treatment.

The possibility of integrating the use of insecticides against other pests while maintaining high activity of the parasitoids against *B. tabaci* has been demonstrated in cotton fields where whitefly populations were kept low, whereas parasitism reached high levels, in spite of treatments against other pests (Figs. 2 and 5). Figure 5 indicates the complexity of the relations within the insecticide-treated agroecosystem and the care that must be taken when analyzing and drawing conclusions from the results of population counts. The population of *B. tabaci* rose in the middle of August and then declined in both the treated plots (using Bifenthrin, Profenophos, and Pyriproxyphen, respectively), and in the controls, in a similar manner. Percentage parasitism rose at the end of August, which correlates well with the strong decline in the host population. However, the rise in parasitism was higher in the treated plots, which by now had received two further treatments (with Bifenthrin and Fenpropathrin). The converse happened in the second cycle of host rise and decline that took place a month (and four more treatments with Monocrotophos) after the first. In that cycle, the untreated population was visibly higher than the treated one but parasitism reached about 70% vs about 28%. In no case did the whitefly populations reach damaging levels. From the above, and from Fig. 2, one can conclude that, in general, the closed canopy in the cotton field during mid and late summer, and the fact that the parasitoids and whiteflies occur under the leaves, afford some protection from insecticide damage. However, the protection is limited and depends on the materials that are used, on their frequency of application, and possibly also on the absolute level of hosts and parasitoids. The relative immunity of the parasitoids was not always shared by predators that are probably more exposed to insecticide treatment. Thus the levels of both *C. carnea* and *Orius* in Zora declined when treatments were used (Fig. 6), and *C. carnea* showed a significant decline in Maale Gilboa (Fig. 7).

OUTDOOR VEGETABLE CULTURE

Virus-related problems that are transmitted by *B. tabaci* are very important in vegetable culture. However, since these require an extremely low presence of whitefly adults in the crop, they are usually dealt with by cultural or insecticidal methods and cannot usually be solved through the use of natural enemies. Consequently, the present discussion will not deal with these but only with the containment of whitefly populations causing direct and honeydew-related damage.

Traditionally, cucurbits, especially melons and cucumbers, were most severely affected by whiteflies and the large populations of *B. tabaci* forming on them caused both direct damage and produced much honeydew (Avidov, 1956). More recently, similar kinds of damage became evident in numerous vegetable species including eggplants, tomatoes, cauliflower, broccoli, and beans. Each of the above has its own complex of pests whose treatment by various means may have a higher priority in the eyes of the grower than biological control of *B. tabaci*. However, recent failures in chemical control and the resulting high whitefly populations have again focused attention on the need to utilize natural enemies to attenuate *B. tabaci*-related problems. The contributions of insecticide treatments in upsetting the activity of natural enemies in vegetables has been suggested following observations that untreated bean plots did not develop whitefly infestation to the same extent as treated ones, and that mature, untreated, broccoli plants had clean top foliage, whereas the lower leaves were covered by *B. tabaci* pupae, all of which were parasitized by *E. mundus*. However, the development of biological control programs requires more exact data as to the occurrence, abundance, effect, and insecticide susceptibility of natural enemies.

Taking a step in this direction, we started to study the fauna of treated vs untreated melon fields in Israel. The results of the first year indicated that the main casualities of insecticide treatments are the predators, whereas the parasitoids are less affected (Figs. 8 and 9). These results are still preliminary and have to be corroborated by further observations, both in the melon crops and others. Moreover, the importance of the various nonspecific predators in the control of *B. tabaci* must be demonstrated before any conclusions can be drawn. However, as could be expected, these findings point to the contribution of the treatments to the upset of the overall balance of beneficial organisms and their possible effects on the pest situation in the field.

GREENHOUSE CULTURE

Mediterranean greenhouse culture includes temporary plastic plant covers and glasshouses. Due to the mild surrounding climate, it is typified by growing both plants and insects actively within and outside the greenhouse throughout most of the year. Thus *B. tabaci* may be introduced with the planting material and/or by flying in from the surroundings where seasonal plants like cotton or potatoes have been harvested.

Many of the problems presented by *B. tabaci* under greenhouse conditions are either associated with viral diseases, with phytotoxic effects, or with esthetics (e.g., tomato viral diseases, squash silvering, or cosmetic damage to poinsettias and roses) which may arise following the feeding by only a few pest individuals. Other problems are due to the rapid population growth that *B. tabaci* exhibits once it is under favorable greenhouse conditions. Here, again, the key to successful biological control lies in the prevention of a population buildup rather than in the reduction of already high populations.

The practice of biological control under such conditions must be integrated with other methods that will prevent damage from occurring and yet facilitate the effective action of the natural enemies. These include mechanical means like screening off the greenhouses (Berlinger *et al.*, 1991) or using row-covers (Perring *et al.*, 1989), utilizing banker plants to expedite the buildup of natural enemies *in situ* without a parallel increase in pest population (Bennison and Corless, 1993), and the judicious use of selective insecticides. The greenhouse environment also affords special conditions amenable to periodic mass release of beneficial organisms and environmental manipulations within their limited space (van Lenteren and Woets, 1988). These can be utilized for the benefit of any program of biological control.

CONCLUSIONS

B. tabaci is a severe pest on numerous crops, in particular annuals and ornamentals. In the Mediterranean countries it is apparent that its initial outbreak phase, which is very difficult to deal with by biological means, is usually followed by a more moderate phase, in which biological control agents can be more effective. However, no one biotic controlling factor (parasitoid, predator, or disease organism) is regularly available, or has been proven to play a decisive role in *B. tabaci* control. Moreover, the factors that are available may not suffice in themselves, and their activity may have to be supplemented by mechanical and/or chemical means.

Of the natural enemies that have been observed, parasitoids are best recorded. However, even here we still rely on the two species that were present in Israel prior to 1976 (Gerling *et al.*, 1980). Studies with predators have just begun, while only a few fungal pathogens are present and others are being developed.

It is evident that considerable efforts should be expended to reduce the capacity of *B. tabaci* to develop in the open countryside, in addition to combating it under particular crop situations. To achieve this, it is necessary to establish additional species of parasitoids and predators. Moreover, a study of the role of each species of beneficial organisms, of the damage levels and insecticide inaction levels (Frisbie *et al.*, 1989), and of alternatives to the use of the upsetting insecticides must be completed. This will enable the integration of their use with commercial applications of agrochemicals and facilitate their optimal usage under the different crop-growing conditions.

The fact that situations exist in which *B. tabaci* does not cause economic damage should be utilized for examining the role of all factors involved, including natural enemies, agrotechnical methodology, the influence of insecticide treatments, and plant conditions. Such studies could reveal which methodology should be encouraged, together with the introduction of natural enemies, in order to bring about better management of *B. tabaci*.

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